Renewable and Sustainable Energy Reviews 14 (2010) 524–529

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review of energy in Rwanda

Bonfils Safari *

Department of Physics, National University of Rwanda, P.O. Box 117, Huye District, South Province, Rwanda

ARTICLE INFO

Article history:
Received 25 March 2009
Accepted 8 July 2009

Keywords:
Energy
Hydro power
Thermal power
Renewable energy
Energy policy
Rwanda

ABSTRACT

During the last two decades, Rwanda has experienced an energy crisis mostly due to lack of investment in the energy sector. With the growing of the population and increasing industrialization in urban areas, energy provided by existing hydro and thermal power plants has been increasingly scarce with high energy costs, and energy instability. Furthermore, as wood fuel is the most important source of energy in Rwanda, the enduring dependence on it and fossil fuel consumption as well, will continue to impact on the process of environmental degradation. Rwanda is rich with abundant renewable energy resources such as methane gas in Lake Kivu, solar, biomass, geothermal; and wind energy resource is currently being explored. Recently, the Government has given priority to the extension of its national electrical grid through development of hydro power generation projects, and to rural energy through development of alternative energy projects for rural areas where access to national grid is still difficult. This paper presents a review of existing energy resources and energy applications in Rwanda. Recent developments on renewable energy are also presented.

Contents

1. Introduction

Rwanda is a small mountainous, landlocked country in the Great Lakes region of Africa. Bordered by the Democratic Republic of the Congo (DRC), Burundi, Tanzania and Uganda, it is located at 2°:00 Latitude South and 30°:00 Longitude East. Total land area is about 24,950 km^2, and inland lakes cover about 1390 km^2.

* Tel.: +250 08508669; fax: +250 530330/122.
E-mail address: bsafari@nur.ac.rw.

1364-0321/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2009.07.009

Nomenclature

SNEL	Société Nationale d'Electricité/R.D. Congo
SINELAC	Société Internationale d'Electricité des Pays des Grands Lacs
CEPGL	Communauté Economique des Pays des Grands Lacs
UEB	Uganda Electricity Board
VAT	value added tax

Rwanda's population of more than 9.1 million (17% urban) is growing at an annual rate of 2.6% and expected to grow to 10 million in 2010, and to 13 million in 2020 with respectively a mean annual growth rate of 2.4 between 2007 and 2010, and 2.0 between 2010 and 2020. The GDP per capita is 365 US$ with an average real GDP growth rate of 10.3% in 2006–2007. The shares of the total GDP sector by sector are 36.4% for agriculture, 14.2% for industry and 43.8% for services and 5.6% for adjustments [1,2]. The electric power generation capacity is very low as compared to its potential and access to energy is very limited. Created in 1976, ELECTROGAZ is a 100% publicly owned company, the unique power grid electricity supplier in the country. At present only 4.3% of the population has access to electricity with 23.4% of the population in urban area and less than 1% in rural areas. The electricity consumption per capita is among the lowest in the world, 30 kWh/year/inhabitant. Per capita power consumption for those connected to the grid is approximately 720 kWh/person/year. Rwanda's grid infrastructure is small and old, and pressured by hasty growth in demand, supply disturbances, and inefficiencies. In Rwanda there are no known crude oil resources and this restricts the country to be completely dependent on imported petroleum products. The transport sector is the main user of petroleum products with 69% of the market, followed by households 16.5% and manufacturing using 14.5% [3].

Rwanda's land area covered by forest is 20% of the total and wood fuel constitutes 80.4% of the total energy consumption. Wood energy is used by 17.7% of the population for light and 98.7% of the population uses wood and charcoal energy for cooking [3,4]. The demand for wood resources is exceeding an exhausted supply and the situation will continue to deteriorate unless policy measures are taken to accelerate the substitution of wood fuel by other forms of alternative energy resources, national forest resources will be depleted. During the last two decades, with the growing of the population and increasing industrialization in urban areas, Rwanda has incessantly experienced energy deficit and this has increased drastically in 2004. The consequence was the rapid growing of the cost of energy per kWh, 17 RWF in 1995, 42 RWF in 1997, 82 RWF in 2005, 112 RWF in 2006 (VAT not included).[1] The Government of Rwanda has taken urgent option of renting thermal power plants, but this was not bringing a sustainable solution.

Meanwhile, the country possesses a very rich hydro power potential, a big amount of methane gas reserve in Lake Kivu estimated at 55 billion m^3 of which 39 billion are economically exploited, a daily global solar radiation of about 5.2 kWh/m^2, peat reserves estimated at 155 millions ton, 1/3 of which is exploitable dry peat, a good potential for geothermal energy estimated at between 170 and 320 MW and wind power potential, but detailed studies need to be conducted for harnessing those resources [4]. Recently with the support of donors, in order to improve the power distribution capacity of the existing network and to support rural electrification, new projects on renewable energy application have been developed. This will help to surmount the situation of energy shortage and environmental degradation the country is being faced to.

2. Energy sources and consumption by sector

Biomass (wood, agriculture residues, charcoal, peat and organic gas) constitutes the major source of energy accounting for 80.40% of the total energy. Fuel and electricity constitute respectively 6% and 0.90% of the total energy. The sources of energy and energy consumption sector by sector in Rwanda are presented in Fig. 1. Of the total energy consumed, households account for 91%, transport sector, industry sector and public services account respectively for 4.5%, 2.7%, and 1.8%. Energy consumed in the rural areas, where the majority of the population lives, is 85% of the total energy. Wood-fuel constitutes 90% of rural energy consumption. The balance 10% is met by other options such as agricultural residues, fuel, charcoal, grid and non-grid electricity, peat, gas, solar and other renewable energies. Wood and charcoal energy is used by 98.7% of the population for cooking and by 17.7% of the population for light.

3. Power energy status

3.1. Power energy generation capacity

In Rwanda, installed electric power generation capacity is very low at 41.25 MW from both Hydro and thermal generation infrastructures. Hydro power accounts for 26.74 MW, while Thermal power generation is now at 14.5 MW. Created in 1976, ELECTROGAZ is a 100% publicly owned company, the unique power grid electricity supplier in the country. Power generation sources in Rwanda are presented in Table 1. ELECTROGAZ power generation comes from Mukungwa, Ntaruka, Gihira and Gisenyi power plants located in the North-Western region. Mukungwa and Ntaruka are the most important on-grid power plants in Rwanda. The Mukungwa station draws water from a Lake Ruhondo that is in

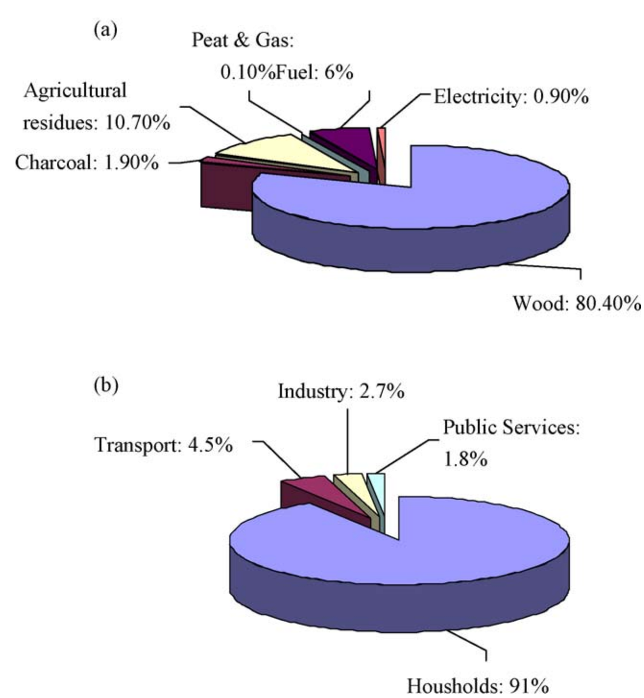


Fig. 1. Sources of energy (a) and energy consumption by sector in Rwanda (b).

[1] Rwandan francs per US$: 262.20 (1995), 585 (2007), 393.44 (2000), 574.62 (2004), 610 (2005), 560 (2006), 553 (2007). [URL: http://www.exchange-rates.org/currentRates/F/RWF].

Table 1
On-grid electrical power energy sources in Rwanda.

Plant	Number of generator units	Year of installation	Installed capacity (MW)	Available (MW)
Hydro power				
Mukungwa	2	1982	12.50	11
Ntaruka	3	1959	11.75	6
Gihira	2	1985	1.84	1.84
Gisenyi	2	1969	1.2	1.2
Total hydro power			26.74	20.04
Thermal				
Gatsata	–	1970	2	–
Jabana	6	2005	7.8	7.8
Gatsata rehabilitated	3	2005	4.77	4.77
Gikondo AGGREKO1 rental	14	2005	10	10
Mukungwa AGGREKO2 rental	7	2005	5	5
Total thermal			29.57	27.57
Solar power				
Jari	–	2007	0.250	0.250
Total solar			0.250	0.250
Imports				
Ruzizi I (SNEL)	–	1958	3.5	3.5
Rusizi II (SINELAC)	–	1989	12	8
Kabale (UEB)	–	–	3	3
Total imports			18.5	14.5
Total power energy			75.06	62.11

turn supplied partly from the Lake Burera for Ntaruka station at a higher elevation (1.864 m). Rwanda also imports electricity through cross-border interconnections of about 15.5 MW from Ruzizi I (SNEL) owned by Congo and from Ruzizi II (SINELAC) co-owned by the three CEPGL countries, and about 3 MW from Uganda (UEB). Recent severe droughts and low water levels in the Lakes have resulted into the purchase of diesel generators (12.5 MW) and renting 15 MW diesel generators from a private company AGGREKO.

Rwanda's grid infrastructure is small and old, and pressured by hasty growth in demand, supply disruptions, and inefficiencies. The main Rwanda's grid infrastructure is presented in Fig. 2. The electricity transmission network has a two main axis grid and it has 285 kilometers of 110 kilovolt lines and 64 km of 70 kV lines. The distribution system consists of both medium voltage (30 kV, 15 kV, and 6.6 kV) and low-voltage (380 V three-phase and 220 V single phase) networks.

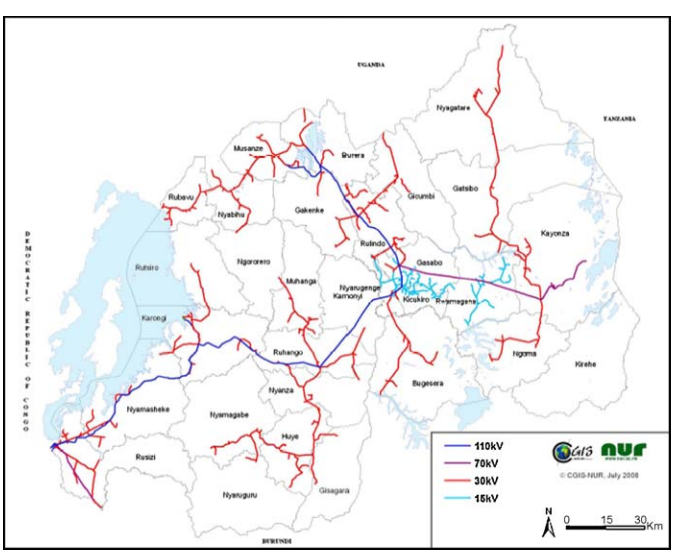


Fig. 2. The main Rwanda's electrical grid infrastructure.

3.2. Power energy production for the period 1997–2007

Energy generated in Rwanda from local production for the period 1997–2007 is presented in Fig. 3. Between around 1997 and 2001, there was heavy drawdown of lake waters at both domestic hydro power stations, which were not replenished due to lower than average rainfall and the consequence was an abrupt decrease of energy generation. From 2003 to 2006, water level in Lake Burera had fallen severely (3.71 m) close to the minimum required (1.69 m higher) in 2004, and generation from both Ntaruka and Mukungwa hydro power stations has been restricted since early January 2004 until end 2005, respectively from 11.25 to 2.5 MW and from 12.45 to 5 MW. The variation of Lake Burera's level for the period 1997–2007 is presented in Fig. 4. The extreme generation drop occurred during a period of increased agricultural activities, increased deforestation while assisting to an economic growth demanding increased electricity supply. By early 2004, the Burundi withdrew from Rusizi II and this caused restriction on ELECTRO-

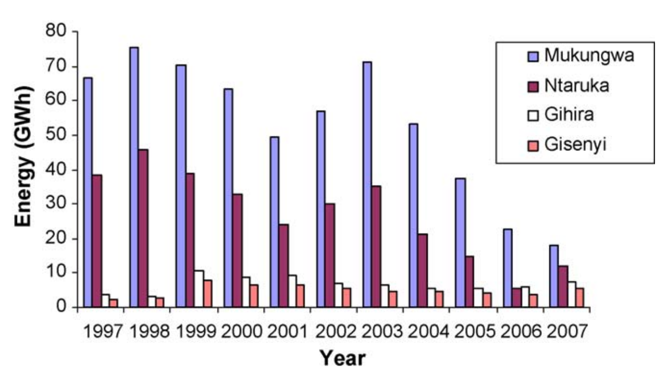


Fig. 3. Total annual hydro energy produced in Rwanda by individual local on-grid power plants for the period 1997–2007.

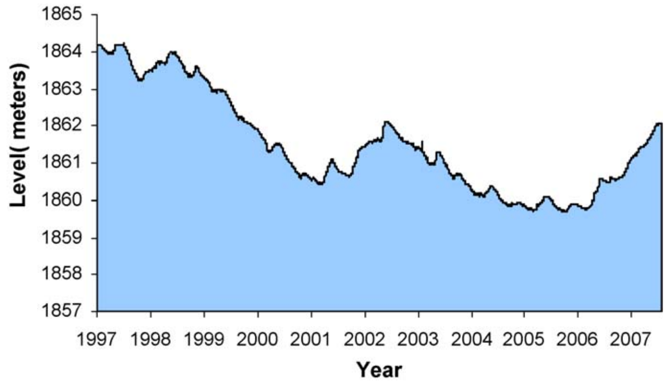


Fig. 4. Variation of the level of Lake Burera for the period 1997–2007.

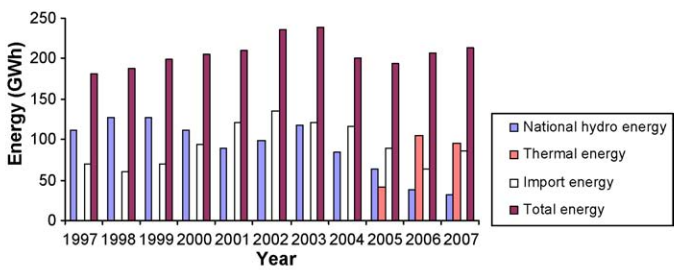


Fig. 5. Total annual energy supplied from hydro and thermal plants, and imported for the period 1997–2007.

GAZ import accessibility and increased the need for still more diesel power generation. KIVU Lake levels have also fallen, resulting in the reduction of output from the Rusizi plants. In reaction to the supply emergency, ELECTROGAZ rapidly rehabilitated the Gatsata diesel generation plant in Kigali and in early 2005, it commissioned 12 MW of new diesel plants at the Gatsata and Jabana substations. Additional to that, and as mentioned above, the Government of Rwanda signed a contract for 15 MW of rental diesel plants with AGGREKO, an independent company. The amounts of total annual energy supplied from hydro and thermal plants, and imported for the period 1997–2007 are presented in Fig. 5. Thermal generation has increased from 0 to 140 GWh, more than a half of the total power energy generation, at the time oil prices have just doubled. An urgent 20 MW electricity generation using heavy fuel oil is under rehabilitation. Heavy fuel oil is cheaper than diesel and therefore can contribute slightly to reduction in tariff. This is potential to replace rental diesel thermal powers from AGGREKO and completion of work is expected in December 2008.

4. Wood energy resource

By 2004, the demand of wood fuel was estimated at 7,562,231 m^3 and the estimated annual extraction potential was 3,186,700 m^3 corresponding to a decline rate in forests of 7%. There was a deficit of 4,375,531 m^3. The growing population and the increasing urbanization have major implications to energy, economic and environment sectors such as growing demand and increasing price of wood fuel, restriction of wood for other economic activities (construction, furniture, etc.), increasing ejection of CO_2 in the atmospheric, soil degradation, drying up of rivers and lakes due to the role of forests as systems of gradual water catchments, climatic consequences, extinction of species of fauna and flora living in the forests. In 1995 the prices for fire wood and charcoal were respectively 700 RWF for one steer (350 kg) and 400 RWF for a bag of charcoal (35 kg). In 2005 the prices have increased to 4200 RWF for one steer of firewood and 5000 RWF for one bag of charcoal. The percentage increase of the prices from 1995 to 2005 represents 600% for firewood and 1250% for charcoal. It manifests that the demand for wood resources is exceeding an exhausted supply and the situation will continue to decline as far as no measures are taken by the Government to reverse that situation. Reforestation can help to restore supply and fuel replacement such as briquettes and energy conservation can reduce demand [5–8].

5. Biogas energy resource

Another alternative source of energy currently being used at a small scale in Rwanda is biogas. The National Domestic Biogas Program (NDBP) aims to promote the use of biogas digesters in rural households. Biogas digesters are mostly used in prisons and schools, where gas is produced with waste from the latrines. This has reduced the costs of cooking in prisons by 50%. Wherever it is done, conversion of human waste into biogas has helped to bring solution to an important environmental concern.

6. Development of alternative energy resources

6.1. Solar energy

Solar energy presents considerable potentials that can contribute to a large extent to fill the gap of energy needs in Rwanda [9,10]. Many technologies have been developed to make use of solar radiation [11–15]. Solar power technologies provide electrical generation by means of heat engines or photovoltaic systems. Solar power technologies are also used for solar water heating systems. Given the geographic location of Rwanda, there is abundant sunshine and the global solar radiation on horizontal surface is ranging between 4.8 $kWhm^{-2}\,day^{-1}$ minimum and 5.5 $kWh\,m^{-2}\,day^{-1}$ maximum [16]. The annual daily mean global solar radiation is about 5.2 $kWh\,m^{-2}\,day^{-1}$ and solar energy becomes an option.

6.1.1. Photovoltaic solar systems (PVs)

Rural electrification is one of the foremost priorities in achieving the Rwandan Government's Vision 2020 with a target of reaching 35% of rural population accessing to electricity. Solar photovoltaic (PV) in Rwanda is almost exclusively used on a small scale of kilowatt peak of solar panels to generate off-grid electricity to be supplied to community centers in remote areas. From 2004 up to now, the Common Development Fund (CDF), the Ministry of Education and the Ministry of Health, with technical assistance from the Ministry of Infrastructure which is in charge of energy, with financial assistance from different donors have realized several PVs projects for the electrification of rural administrative units, schools, hospitals and health centers. The following public entities are electrified by grid connection: 84% of administrative offices of districts, 23% of administrative offices of sectors, 11% of primary schools, 52% of secondary schools, 85% of district hospitals, and 26% of health centers. The remaining non-grid-connected are using either diesel generators or stand-alone solar power systems. In addition to the above off-grid solar PV systems in rural area, there is an on-grid solar PV Power Plant project of 1 MW known as Kigali Solar Project. The first phase of this project of 250 kW has been completed on Mount Jali in Kigali and has been officially inaugurated on June 7, 2007. This is the biggest solar power plant in Africa and the electricity generated out of it is connected to the national grid. ELECTROGAZ will have to extend the national grid to one of the rural area district, Kamonyi district, for them to use the electricity generated from

Kigali solar project. The Solar power plant was developed by the ministry of infrastructure with the support of the Stadtwerke Mainz, the power utility of the German state of Rhineland-Palatinate.

6.1.2. Solar water heating systems (SWHS)

Solar water heating is the most attractive application of solar energy; due its simplicity to construction and negligible maintenance and running cost. Currently, most of hot water users for commercial or domestic purposes, in urban areas of Rwanda, utilize electric power to heat the water. As a result, hot water heating represents a large portion of their electrical expenses. At present, one electric water heater costs approximately 200 US$. Based on the current price of electricity, on average it would cost per year 400 US$ to a household to heat a water tank using 5 kWh. Solar water heating made with available local materials costs approximately 1500 US$, the energy used is free that makes it economical compared to electric water heater. Several domestic solar water heaters were installed in Butare city before the Genocide of 1994. Unfortunately these systems are no more working because they are old and have never been replaced or rehabilitated. Presently, studies are conducted by researchers at the Institute of Scientific Research and Technology (IRST) on the potential of using water heaters for domestic and industrial applications.

6.2. Wind energy

Wind energy can be exploited wherever the wind regime allows, and could thus distribute power to remote areas from national grid [17,18]. To date in Rwanda, wind energy has been used in only two sites: a wind powered electricity turbine was installed at the Mont Karisimbi's summit (4507 AMSL) for the FM transceiver antenna of the National Radio and Television, unluckily, it was destroyed during the 1994 Genocide; a wind turbine for pumping water (3 $m^3 h^{-1}$) is installed at Gabiro district, in the Northern Province. At Remera-city of Kigali there is a 1 kW wind turbine developed by a private owner for the purpose of supplying electricity to a cyber network. With the growing demand of electricity, the Government of Rwanda is trying to diversify its energy sources as much as possible in exploring possibilities of wind energy development. Recently, the ministry of energy commissioned a feasibility study to determine the wind power capacity of Rwanda.

6.3. Geothermal energy

This form of energy is available as heat emitted from within the earth's crust, usually in the form of hot water or steam, and it can be exploited for electricity generation [19]. Rwanda is located in a region of intensive volcanic activities and there is evidence of existence of geothermal field that could be harnessed for energy purpose. Three sites in the Western Province (Cyangugu, Kibuye and Gisenyi) were identified by the French bureau BRGM (Bureau de Recherche Géologique et Minière) in the 1980's with geothermal energy potential between 170 and 300 MW based on work carried out at a hydrothermal spring in the western part of the country. In 2006, the American company Chevron confirmed the potential after two geothermal explorations. According to a recent study by Geothermal Energy Association, geothermal potential in Rwanda ranges from 170 to 340 MW. However, to date no investment has been made in this area as power generation using geothermal energy was considered an expensive process. The ministry of infrastructure has commanded a feasibility study for the construction of geothermal power plants by 2010.

6.4. Methane gas

The KIVU Lake hosts enough reserves of methane gas estimated at 55 billion m^3 of which 39 billion are economically exploited, meaning the equivalence of 32 million of PET (petroleum equivalent tone). An estimated power of 700 MW can be obtained from methane gas. The Kibuye Power One (KP1) Project has been initiated as a joint venture into which the Government and private investors have entered into an agreement to generate power from methane gas. A pilot gas plant of 5 MW is under construction on the Lake's North-Eastern shore and if the technology is proven successful in terms of safe and economic extraction, it is expected to have completed the second phase of 40 MW in Kibuye by 2010. Long-term concessions and power purchase agreements being negotiated with various investors are targeting 350 MW in the next 10 years increasing the national capacity almost 10-fold.

6.5. Hydro power

The feasibility study of the Nyabarongo hydro power project with a capacity of 27.5 MW has been completed and the project funding is estimated at USD 80 Million. A credit has been obtained through public–private partnership from Export and Import Bank of India. Two Indian companies known as BHEL and Angelique International Limited. EPC signed a contract on July 8th 2008 for engineering, procurement and construction (EPC). The execution period is 45 months. The Rukarara hydro power project with a capacity of 9.5 MW is ongoing where the construction works were contracted to a private Sri Lankan Company named Eco-power Global Limited and started in February 2007 while the supervision contract was awarded to a Chinese Firm Beijing Forever Technology Development Company (FOREVER). Total cost of construction and supervision is estimated at about US$ 20 million and the power output expected mid 2010. The regional Rusumo hydro power project with a capacity of 60 MW is under studies carried out by a Canadian company known as SNC Lavalin under World Bank financing estimated at US$ 115 million. The power will be shared equally between the three countries (20 MW Burundi, 20 MW Rwanda and 20 MW Tanzania). The study for high voltage transmission lines will be carried out under the African Development Bank financing estimated at US$ 39 million. It will comprise a backbone transmission interconnection system comprising transmission lines from the hydro power plant to the nearest substation in each of the three countries, and a regional load dispatching center. A multi-purpose rural development, and catchments management component that will address watershed, social and environmental issues, and private sector economic development will be defined through a participatory process and will be linked to the broader multi-purpose development program of the Kagera basin. Funds are to be sourced for implementation. The first phase regional Rusizi III Power Project is located on the DR Congo/Rwanda border and has a potential to produce 210 MW. Funds required to carry out feasibility study for this phase (145 MW) have been secured from the European Union. The study was expected to end in December 2008. The pre-feasibility study of the second phase Rusizi IV (205 MW) was expected to end in March 2009.

6.6. Rural decentralized micro hydro power

The Government of Rwanda has undertaken actions for the development of rural energy in places where access to national grid is still difficult. It had commissioned the construction of micro hydro powers at eight sites totaling 6.4 MW. All sites are under construction, and are expected to be online by end 2009; six micro hydro powers of total 1.6 MW are currently being developed by

private companies in collaboration with ELECTROGAZ and are funded by Dutch-German partnership, energizing development; the Belgian Technical Cooperation has planned to support three districts in building five micro hydro power plants of total 5.13 MW ; the EU–energy facility in collaboration with the Government of Rwanda has planned to develop 3 MW micro hydro power. Beneficiaries are districts, sectors, schools community/health/trading centers and households.

7. Conclusion

During the last two decades, Rwanda has known an energy crisis which has led the country to be more reliant to import and by 2004 until now, as a matter of urgency, to be mostly dependant to thermal generation at the time oil prices have drastically increased. In its plans, with the support of donors, the Government of Rwanda has taken measures in order to supply energy in a more sustainable way. The national electricity utility ELECTROGAZ has started to renew the installed power stations and also to install new hydro power plants. Located in the western region of the country, Lake Kivu has a valuable potential of Methane Gas for electricity generation to be injected in the national grid. The Government of Rwanda in partnership with private investors has undertaken the construction of KP1 a pilot gas plant of 5 MW on the Lake's North-Eastern shore. It is expected to have completed the second phase of 40 MW in Kibuye by 2010. In rural areas where rural electrification is poor and wood fuel is the most type of energy means of consumption, the Government of Rwanda has undertaken actions for the development of rural energy through development of micro hydro power plants in places where access to national grid is still difficult. Furthermore, the Government of Rwanda is promoting the use of solar energy for electrification in districts, schools and hospitals. Development of PV-systems and possibly windmill for electrification of households and water pumping for drinking and agricultural purposes in rural areas is a priority for the Government towards the achievement of the Government's Vision 2020 with a target of reaching 35% of rural population accessing to electricity and 100% of the population accessing to clear water. The NDBP aims to promote the use of biogas digesters in rural households.

Acknowledgements

The author is grateful to ELECTROGAZ, the Ministry of Infrastructure, and the Ministry of Natural Resources for providing relevant information for this article. The present study has been supported by the Research Commission of the National University of Rwanda (NUR) through a partnership with Swedish International Agency SIDA/SAREC.

References

[1] Economic Development and Poverty Reduction Strategy in Rwanda-EDPRS, 2008–2012,URL: http://www.minecofin.gov.rw; September 2007.
[2] Annual report 2007, National Bank of Rwanda, URL: http://www.bnr.rw/publications.aspx; June 2008.
[3] General Census of Population and Housing 16–30, 2002. Republic of Rwanda, Ministry of Finance and Economic Planning. URL: http://www.statisticsrwanda.gov.rw/; February 2003.
[4] Energy Policy for Rwanda. Republic of Rwanda, Ministry of Infrastructure, URL: http://www.upegaz.gov.rw/Rwanda___Energy_Policy_for_Rwanda__final____10_2004__W0695884_.DOC; October 2004.
[5] Hategeka A, Karenzi PC. Guidelines for biomass energy policy implementation in Rwanda. Biomass Energy Policy Afr 1997;145–221. London (United Kingdom), Zed Books. ISBN 1-85649-520-5.
[6] Karekezi S, Majoro L. Improving modern energy services for Africa's urban poor. Energy Policy 2002;30:1015–28. doi: 10.1016/S0301-4215(02)00055-1.
[7] Utilization characteristics and importance of woody biomass resources on the rural-urban fringe in Botswana. Environmental Management, 2006;37 (2):281–296. doi:10.1007/s00267-005-2776-4.
[8] Kammen DM , Lew DJ. Review of Technologies for the Production and Use of Charcoal. Renewable and Appropriate Energy Laboratory Report, URL: http://rael.berkeley.edu/files/2005/Kammen-Lew-Charcoal-2005.pdf; March 1, 2005, pp. 19.
[9] Okoro OI, Madueme TC. Solar energy: a necessary investment in a developing economy. Int J Sustain Energy 2006;25(1):23–31. doi: 10.1080/14786450600593147.
[10] Lujara N, Kaunde O. Solar photovoltaic systems as an alternative source of energy in Rwanda: Kigali City case study. In: Proceedings of the Ninth IASTED International Conference on Power and Energy Systems; 2007, http://www.actapress.com/Content_Of_Proceeding.aspx?ProceedingID=423#pages.
[11] Scheer H, Kerrley A. The solar economy: renewable energy for a sustainable global future. London: Earthscan Publications Ltd.; 2002 . pp. 347, ISBN: 1853838357.
[12] Zekai Sen. Solar energy fundamentals and modeling techniques: atmosphere, environment, climate change and renewable energy. Springer; 2008. doi: 10.1007/978-1-84800-134-3. pp. 276, ISBN: 978-1-84800-133-6.
[13] Dunn PD. Renewable energies: sources, conversion and application. New York: Peter Peregrinus Ltd.; 1986. pp. 373, ISBN: 978-0863410390.
[14] Edinger R, Kaul S. Humankind's detour toward sustainability: past, present and future of renewable energies and electric power generations. Renew Sustain Energy Rev 2000;4:295–313. doi: 10.1016/S1364-0321(99)00017-9.
[15] URL: http://en.wikipedia.org/wiki/Solar_energy.
[16] Safari B, Gasore J. Estimation of Global Solar Radiation in Rwanda Using Empirical Models. Asian J Sci Res 2009;2(2):68–75. doi: 10.3923/ajsr.2009.68.75.
[17] Joselin Herbert GM, Iniyan S, Sreevalsan E, Rajapandian S. A review of wind energy technologies. Renew Sustain Energy Rev 2007;11:1117–45. doi: 10.1016/j.rser.2005.08.004.
[18] DWIA, Danish Wind Industry Association, "Guided Tour on wind energy", Denmark, URL: http://www.windpower.org/en/tour.htm; 2002.
[19] Geothermal Basics Overview. Office of Energy Efficiency and Renewable Energy. URL: http://www1.eere.energy.gov/geothermal/geothermal_basics.html.